AMENDMENTS TO THE CLAIMS

The following listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (Previously Presented) A joint moment estimation method for a two-legged walking mobile body, for estimating a joint moment acting on at least one joint of each leg of the two-legged walking mobile body by using a rigid link model in which the two-legged walking mobile body is represented as a link body where a plurality of rigid elements are coupled together by a plurality of joint elements including at least joint elements corresponding to a hip joint and a knee joint of each leg of the two-legged walking mobile body, the method comprising:

a first step of sequentially grasping displacements of the respective joints of the two-legged walking mobile body corresponding to the respective joint elements of the rigid link model;

a second step of sequentially grasping values in a body coordinate system of an acceleration vector of the origin of the body coordinate system, which has been preset as a coordinate system fixed to and tilting with one predetermined rigid element of the rigid link model, by using at least an output of an acceleration sensor attached to the two-legged walking mobile body;

a third step of sequentially grasping values in the body coordinate system of a floor reaction force vector acting on each leg of the two-legged walking mobile body;

a fourth step of sequentially grasping values in the body coordinate system of a position vector of a point of application of the floor reaction force vector; and

a fifth step of sequentially estimating joint moments acting on at least one joint of each leg of the two-legged walking mobile body on the basis of an inverse dynamics model representing a relation between a motion of each rigid element of the rigid link model and a translational force and moment acting on the rigid element in the body coordinate system by using the displacements of the respective joints of the two-legged walking mobile body grasped in the first to fourth steps, the value of the acceleration vector of the origin in the body coordinate system, the value of the floor reaction force vector, and the value of the position vector of the point of application of the floor reaction force vector.

2. (Original) The joint moment estimation method for the two-legged walking mobile body according to claim 1, wherein the acceleration sensor is attached to a rigid equivalent part of the two-legged walking mobile body corresponding to the rigid element to which the body coordinate system is fixed.

3. (Original) The joint moment estimation method for the two-legged walking mobile body according to claim 2, wherein the rigid element to which the body coordinate system is fixed is a rigid element connecting a pair of joint elements corresponding to a pair of hip joints of the two-legged walking mobile body.

4. (Original) The joint moment estimation method for the two-legged walking mobile body according to claim 1, further comprising:

a sixth step of sequentially calculating values in the body coordinate system of a position vector of an total center-of-gravity of the two-legged walking mobile body by using the displacements of the respective joints of the two-legged walking mobile body grasped in the first step and the rigid link model;

a seventh step of sequentially grasping values in the body coordinate system of the acceleration vector of the total center-of-gravity from time-series data of the value of the position vector of the total center-of-gravity and the value of the acceleration vector of the origin of the body coordinate system grasped in the second step; and

an eighth step of sequentially determining whether the motion state of the two-legged walking mobile body is a one-leg supporting state in which only one leg of a pair of legs is landing or a two-leg supporting state in which both legs are landing,

wherein the third step includes: estimating the value in the body coordinate system of the floor reaction force vector on the basis of the equation of motion of the total center-of-gravity of the two-legged walking mobile body represented by the value of the acceleration vector of the total center-of-gravity calculated in the seventh step, the total weight of the two-legged walking mobile body, and the floor reaction force vector acting on the landing leg if the motion state of the two-legged walking mobile body is the one-leg supporting state; and grasping the values in the body coordinate system of the floor reaction force vectors acting on both legs respectively on the basis of the equation of motion of the total center-of-gravity of the two-legged walking mobile body represented by the value of the acceleration vector of the total center-of-gravity calculated in the seventh step, the total weight of

the two-legged walking mobile body, and the floor reaction force vectors acting on the both legs respectively and a relational expression between a relative position of a specific portion of each of the legs to the total center-of-gravity of the two-legged walking mobile body, which is determined on the assumption that the floor reaction force vector acting on the leg is a vector acting from the specific portion predetermined in the vicinity of the lower end of the leg toward the total center-of-gravity of the two-legged walking mobile body, and the floor reaction force vector acting on the leg if the motion state of the two-legged walking mobile body is the two-leg supporting state.

5. (Original) The joint moment estimation method for the two-legged walking mobile body according to claim 1, further comprising:

a ninth step of sequentially grasping tilt angles to the vertical direction of the rigid equivalent part of the two-legged walking mobile body corresponding to the rigid element to which the body coordinate system is fixed;

a tenth step of determining whether or not the leg is landing for each of the legs of the two-legged walking mobile body;

an 11th step of grasping at least a value in the body coordinate system of the position vector of the total center-of-gravity of the two-legged walking mobile body, a value in the body coordinate system of the position vector of the ankle joint of the landing leg, and a value in the body coordinate system of the position vector of a metatarsophalangeal joint of the foot of the leg by using the displacements of the respective joints of the two-legged walking mobile body grasped in the first step and the rigid link model;

a 12th step of grasping at least the positional relationship among the total center-of-gravity, the ankle joint of the landing leg, and the metatarsophalangeal joint of the foot of the leg and the vertical position of the ankle joint of the leg on the basis of the position vector values of the total center-of-gravity, the ankle joint of the landing leg, and the metatarsophalangeal joint of the foot of the leg having been grasped and the tilt angle grasped in the ninth step; and

a 13th step of estimating a horizontal in-plane position of the point of application of the floor reaction force vector acting on the landing leg on the basis of the grasped positional relationship among the total center-of-gravity, the ankle joint of the landing leg, and the metatarsophalangeal joint of the foot of the leg and estimating the vertical position of the point of application of the floor reaction force vector acting on the leg on the basis of the vertical position of the ankle joint of the leg,

wherein the fourth step includes a step of grasping a value of the position vector of the point of application of the floor reaction force vector in the body coordinate system on the basis of the horizontal in-plane position and the vertical position of the point of application of the floor reaction force vector estimated in the 13th step and the tilt angle grasped in the ninth step.

6. (Original) The joint moment estimation method for the two-legged walking mobile body according to claim 5, wherein:

the values of the floor reaction force vector and the position vector of the point of application of the floor reaction force vector grasped in the third step and the fourth step, respectively, are three-dimensional values; and

the 13th step includes a step of: estimating the horizontal in-plane position of the ankle joint of the landing leg as the horizontal in-plane position of the point of application of the floor reaction force vector acting on the leg if the total center-of-gravity is more backward than the ankle joint of the landing leg in the forward/backward direction of the two-legged walking mobile body; estimating the horizontal in-plane position of the metatarsophalangeal joint of the foot of the landing leg as the horizontal in-plane position of the point of application of the floor reaction force vector acting on the leg if the total center-of-gravity is more forward than the metatarsophalangeal joint of the foot of the landing leg in the forward/backward direction of the two-legged walking mobile body; and estimating the horizontal in-plane position of the point whose position in the forward/backward is coincident with the total center-of-gravity on the line segment connecting the ankle joint with the metatarsophalangeal joint of the landing leg as a horizontal in-plane position of the point of application of the floor reaction force vector acting on the leg if the total center-of-gravity is more forward than the ankle joint of the landing leg in the forward/backward direction of the two-legged walking mobile body and is more backward than the metatarsophalangeal joint of the foot of the leg.

7. (Previously Presented) The joint moment estimation method for the two-legged walking mobile body according to claim 5, wherein the 13th step includes a step of estimating the vertical position of the point of application of the floor reaction force vector acting on the landing leg as a position located a predetermined value apart from the vertical position of the ankle joint of the leg grasped in the 12th step downward in the vertical direction.

8. (Original) The joint moment estimation method for the two-legged walking mobile body according to claim 7, wherein:

the 10th step includes a step of determining whether each of the toe-side portion and the heel-side portion of the foot of the leg is in contact with the ground regarding the leg determined to be landing;

the 12th step includes a step of grasping the vertical position of the metatarsophalangeal joint of the foot of the leg in addition to the vertical position of the ankle joint of the landing leg; and

the 13th step includes a step of estimating the vertical position of the point of application of the floor reaction force vector by using a distance in the vertical direction between the ankle joint and the metatarsophalangeal joint obtained from the vertical position of the ankle joint and the vertical position of the metatarsophalangeal joint grasped in the 12th step, instead of the predetermined value, if only the toe-side portion is determined to be in contact with the ground among the toe-side portion and the heel-side portion of the foot in the 10th step.

9. (Previously Presented) The joint moment estimation method for the two-legged walking mobile body according to claim 1, wherein the value of the floor reaction force vector and the value of the position vector of the point of application of the floor reaction force vector respectively grasped in the third step and the fourth step are three-dimensional values.

10. (Previously Presented) The joint moment estimation method for the two-legged walking mobile body according to claim 6, wherein the 13th step includes a

step of estimating the vertical position of the point of application of the floor reaction force vector acting on the landing leg as a position located a predetermined value apart from the vertical position of the ankle joint of the leg grasped in the 12th step downward in the vertical direction.

11. (Previously Presented) The joint moment estimation method for the two-legged walking mobile body according to claim 10, wherein:

the 10th step includes a step of determining whether each of the toe-side portion and the heel-side portion of the foot of the leg is in contact with the ground regarding the leg determined to be landing;

the 12th step includes a step of grasping the vertical position of the metatarsophalangeal joint of the foot of the leg in addition to the vertical position of the ankle joint of the landing leg; and

the 13th step includes a step of estimating the vertical position of the point of application of the floor reaction force vector by using a distance in the vertical direction between the ankle joint and the metatarsophalangeal joint obtained from the vertical position of the ankle joint and the vertical position of the metatarsophalangeal joint grasped in the 12th step, instead of the predetermined value, if only the toe-side portion is determined to be in contact with the ground among the toe-side portion and the heel-side portion of the foot in the 10th step.

12. (Previously Presented) The joint moment estimation method for the two-legged walking mobile body according to claim 4, wherein the value of the floor reaction force vector and the value of the position vector of the point of application of

the floor reaction force vector respectively grasped in the third step and the fourth step are three-dimensional values.

13. (Previously Presented) The joint moment estimation method for the two-legged walking mobile body according to claim 5, wherein the value of the floor reaction force vector and the value of the position vector of the point of application of the floor reaction force vector respectively grasped in the third step and the fourth step are three-dimensional values.